Appendix A

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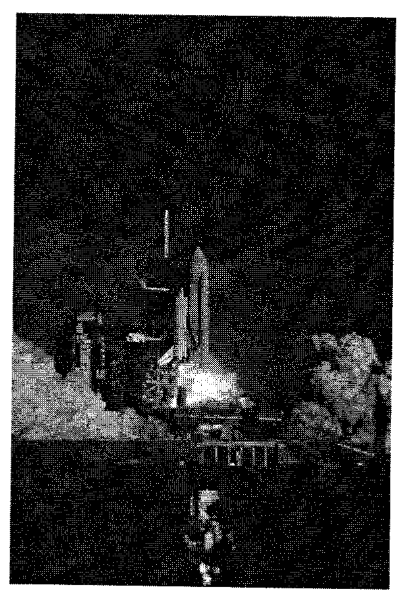
Kapton® is used in applications such as the solar array and for thermal management in the United States space program.



General Information

Kapton® polyimide film possesses a unique combination of properties that make it ideal for a variety of applications in many different industries. The ability of Kapton® to maintain its excellent physical, electrical, and mechanical properties over a wide temperature range has opened new design and application areas to plastic films.

Kapton® is synthesized by polymerizing an aromatic dianhydride and an aromatic diamine. It has excellent chemical resistance; there are no known organic solvents for the film. Kapton® does not melt or burn as it has the highest UL-94 flammability rating: V-0. The outstanding properties of Kapton® permit it to be used at both high and low temperature extremes where other organic polymeric materials would not be functional.

Adhesives are available for bonding Kapton® to itself and to metals, various paper types, and other films.

Kapton® polyimide film can be used in a variety of electrical and electronic insulation applications: wire and cable tapes, formed coil insulation, substrates for flexible printed circuits, motor slot liners, magnet wire insulation, transformer and capacitor insulation, magnetic and pressure-sensitive tapes, and tubing. Many of these applications are based on the excellent balance of electrical, thermal, mechanical, physical, and chemical properties of Kapton® over a wide range of temperatures. It is this combination of useful properties at temperature extremes that makes Kapton® a unique industrial material.

Three types of Kapton® are described in this bulletin:

- Kapton® Type HN, all-polyimide film, has been used successfully in applications at temperatures as low as –269°C (– 452°F) and as high as 400°C (752°F).

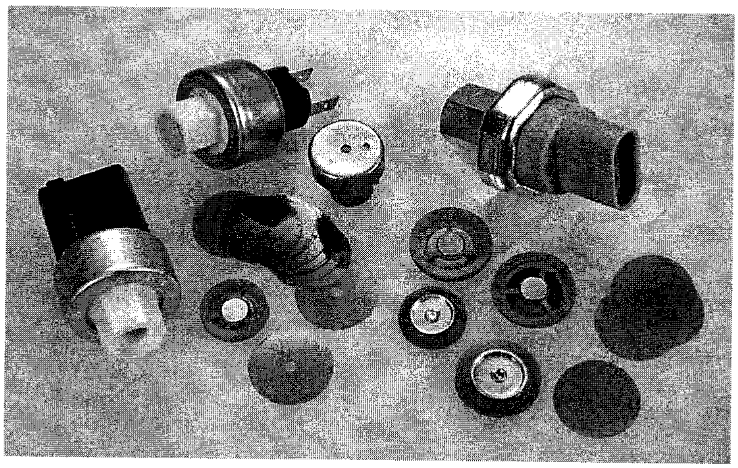
  Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 μm (0.3 mil), 12.5 μm (0.5 mil), 19 μm (0.75 mil), 25 μm (1 mil), 50 μm (2 mil), 75 μm (3 mil), and 125 μm (5 mil) films.
- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 μm (0.5 mil), 19 μm (0.75 mil), 25 μm (1 mil), 50 μm (2 mil), 75 μm (3 mil), and 125 μm (5 mil) films.
- Kapton® Type FN, a Type HN film coated on one or both sides with Teflon® FEP fluoropolymer resin, imparts heat sealability, provides a moisture barrier, and enhances chemical resistance. Type FN is available in a number of combinations of polyimide and Teflon® FEP thicknesses (see **Table 16**).

Note: In addition to these three types of Kapton®, films are available with the following attributes:

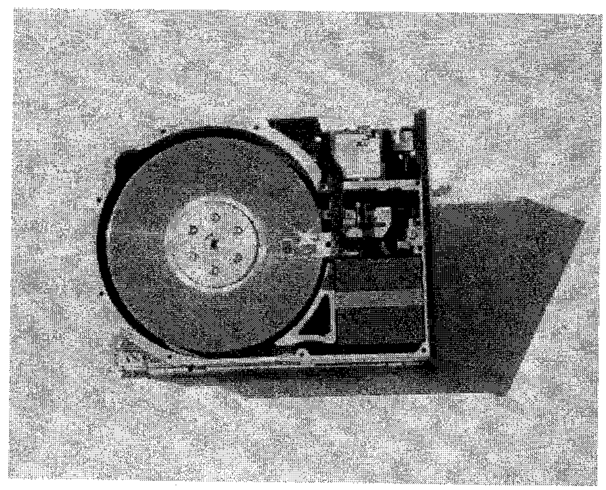
- antistat
- thermally conductive
- polyimides for fine line circuitry
- cryogenic insulation
- corona resistant
- pigmented for color
- conformable
- other films tailored to meet customers' needs

Data for these films are covered in separate product bulletins, which can be obtained from your DuPont representative.

The Chemical Abstracts Service Registry Number for Kapton® polyimide film is [25036-53-7].



Kapton® withstands the harsh chemical and physical demands on diaphragms used in automotive switches.



Kapton® is used in numerous electronic applications, including hard disk drives.

Physical and Thermal Properties

Kapton® polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures were as low as –269°C (–452°F) and as high as 400°C (752°F). Complete data are not available at these extreme conditions, and the majority of technical data presented in this section falls in the 23 to 200°C (73 to 392°F) range.

Table 1
Physical Properties of Kapton® Type 100 HN Film, 25 μm (1 mil)

Physical Property	Typical Value at 23°C (73°F)	Typical Value at 200°C (392°F)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N·cm (ft·lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
Poisson's Ratio	0.34		Avg. Three Samples Elongated at 5%, 7%, 10%
Low Temperature Flex Life	Pass		IPC TM 650, Method 2.6.18

*Specimen Size: 25 × 150 mm (1 × 6 in); Jaw Separation: 100 mm (4 in); Jaw Speed: 50 mm/min (2 in/min); Ultimate refers to the tensile strength and elongation measured at break.

Table 2
Thermal Properties of Kapton® Type 100 HN Film, 25 μm (1 mil)

Thermal Property	Typical Value	Test Condition	Test Method
Melting Point	None	None	ASTM E-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	–14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivity, W/m·K	0.12	296 K	ASTM F-433-77 (1987)$^{\epsilon 1}$
$\frac{\text{cal}}{\text{cm·sec·°C}}$	2.87×10^{-4}	23°C	
Specific Heat, J/g·K (cal/g·°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-85)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = <1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (T_g)	A second order transition occurs in Kapton® between 360°C (680°F) and 410°C (770°F) and is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

Appendix B

Polyimide
PI

Click here to return to materials

Find products containing this material in the following form: All Search

Common Brand Names: Kapton, Kinel, Upilex, Upimol, Vespel

General Description:

General Description : Normally infusible, coloured (often amber) high performance polymers with predominantly aromatic molecules of high thermal stability. Semi-fabricated shapes are usually supplied by the polymer manufacturer and made by powder sintering or working with more tractable pre-cursors and completing polymerisation in final form, though some melt-processable grades of resin are manufactured. They have excellent high temperature properties and radiation resistance, inherently low flammability and smoke emission, low creep and high wear resistance and are very expensive. They have moderately high water absorption and are prone to hydrolysis and attack by alkalis and concentrated acids.

A widely used form is Kapton® film, made in thicknesses from 0.008 to 0.125mm and which is a transparent amber colour. Thicker polyimide items are usually opaque. A range of Kapton film variants are also available. In each of these, a large measure of Kapton's basic properties are combined with an extra attribute eg increased electrical or thermal conductivity, improved corona resistance, opacity and thermoplasticity.

Films are used for capacitators, insulation, printed circuit boards and in aerospace; other applications include engine components, bearings and mechanical parts exposed to radiation.

Explanation of Kapton grade descriptions

HN Regular Kapton - Transparent Amber

CB Opaque black version of HN

MT Aluminium oxide filled, increased thermal conductivity, opaque yellow

MTB Opaque black version of MT

CR Improved corona resistance - translucent yellow

XC Electrically (semi-)conductive - opaque black

KJ Thermoplastic - transparent yellow

Chemical Resistance

Acids - concentrated	Poor

Acids - dilute	Fair
Alcohols	Poor
Alkalis	Poor
Aromatic hydrocarbons	Good
Greases and Oils	Good
Halogenated Hydrocarbons	Good
Halogens	Fair
Ketones	Good

Electrical Properties

Dielectric constant @1MHz	3.4
Dielectric strength ($kV\ mm^{-1}$)	22
Dissipation factor @ 1kHz	0.0018
Surface resistivity (Ohm/sq)	10^{16}
Volume resistivity (Ohmcm)	10^{18}

Mechanical Properties

Coefficient of friction	0.42
Elongation at break (%)	8-70
Hardness - Rockwell	E52-99
Izod impact strength ($J\ m^{-1}$)	80
Tensile modulus (GPa)	2.0-3.0
Tensile strength (MPa)	70-150

Physical Properties

Density ($g\ cm^{-3}$)	1.42
Flammability	V0
Limiting oxygen index (%)	53
Radiation resistance	Good
Refractive index	1.66
Resistance to Ultra-violet	Poor
Water absorption - over 24 hours (%)	0.2-2.9

Thermal Properties

Coefficient of thermal expansion ($x10^{-6}\ K^{-1}$)	30-60
Heat-deflection temperature - 1.8MPa (C)	360
Lower working temperature (C)	-270
Specific heat ($J\ K^{-1}\ kg^{-1}$)	1090
Thermal conductivity ($W\ m^{-1}\ K^{-1}$)	0.10-0.35 @ 23C
Upper working temperature (C)	250-320

Properties Polyimide Film

Property		Value				
Material		HN	CB	MT	MTB	CR
Coefficient of thermal expansion	$x10^{-6}\ K^{-1}$	20				
Corona Resistance @ 20kV mm^{-1} 50 Hz	hr	200				>100,
Density	$g\ cm^{-3}$	1.42	1.42	1.85	1.85	1.54
Dielectric Constant @ 1MHz		3.4				
Dielectric Constant @ 1kHz		3.4	4.5	4.2	4.2	3.9
Dielectric Strength @25μm thick	$kV\ mm^{-1}$	300	80	165	70 @ 0.075mm	290
Dissipation Factor @1MHz		0.01				
Dissipation Factor @1kHz		0.0018	0.19			0.003
Elongation at Break	%	70	45	50-60	50-60	45

Initial Tear Strength	g μm^{-1}	20				
Moisture absorption	%	2.8		3	3	
Permeability to Carbon Dioxide @25C	$x10^{-13}$ cm^3. cm cm^{-2} s^{-1} Pa^{-1}	0.5				
Permeability to Hydrogen @25C	$x10^{-13}$ cm^3. cm cm^{-2} s^{-1} Pa^{-1}	1				
Permeability to Nitrogen @25C	$x10^{-13}$ cm^3. cm cm^{-2} s^{-1} Pa^{-1}	0.03				
Permeability to Oxygen @25C	$x10^{-13}$ cm^3. cm cm^{-2} s^{-1} Pa^{-1}	0.1				
Permeability to Water @25C	$x10^{-13}$ cm^3. cm cm^{-2} s^{-1} Pa^{-1}	400				
Permeability to Water @38C	$x10^{-13}$ cm^3. cm cm^{-2} s^{-1} Pa^{-1}	500				
Shrinkage @400C	%	1.2-1.5	1	1	1	0.6
Surface Resistivity	Ohm/sq					3.6x1
Tensile modulus	GPa	2.5	2.7	4	4	3.2
Tensile strength	MPa	230	135	125	125	150
Thermal Conductivity @23C	W m^{-1} K^{-1}	0.16		0.45	0.45	0.38
Volume Resistivity	Ohmcm	$1.5x10^{17}$	10^{13}	10^{14}	10^{14}	2.3x1

Properties Polyimide Chopped Fibre

Property		Value
Specific Tenacity	cN/tex	38
Extension to break	%	30
Limiting Oxygen Index	%	38
Shrinkage @180C	%	<1
Tenacity	GPa	540

Click here to return to materials

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Appendix C

Appendix A

Thermal Conductivity of some common Materials

Thermal conductivity of some common materials as aluminum, asphalt, brass, copper, steel and many more

Thermal conductivity is the quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area, due to a unit temperature gradient under steady state conditions.

Thermal conductivity, or heat transfer coefficients, of some common materials and products can be found in the table below:

Thermal Conductivity - *k* - (W/m K)			
Material/Substance	Temperature (°C)		
	25	125	225
Acetone	0.16		
Acrylic	0.2		
Air	0.024		
Alcohol	0.17		
Aluminum	250	255	250
Aluminum Oxide	30		
Ammonia	0.022		
Antimony	18.5		
Argon	0.016		
Asbestos-cement board	0.744		
Asbestos-cement sheets	0.166		
Asbestos-cement	2.07		
Asbestos, loosely packed	0.15		
Asbestos mill board	0.14		
Asphalt	0.75		
Balsa	0.048		
Bitumen	0.17		
Benzene	0.16		
Beryllium	218		
Brass	109		
Brick dense	1.31		
Brick work	0.69		
Cadmium	92		
Carbon	1.7		
Cement, portland	0.29		
Cement, mortar	1.73		
Chalk	0.09		
Cobalt	69		

Thermal Conductivity of some common Materials

Concrete, light	0.42		
Concrete, stone	1.7		
Constantan	22		
Copper	401	400	398
Corian (ceramic filled)	1.06		
Corkboard	0.043		
Cork, regranulated	0.044		
Cork, ground	0.043		
Cotton	0.03		
Carbon Steel	54	51	47
Cotton Wool insulation	0.029		
Diatomaceous earth (Sil-o-cel)	0.06		
Earth, dry	1.5		
Ether	0.14		
Epoxy	0.35		
Felt insulation	0.04		
Fiberglass	0.04		
Fiber insulating board	0.048		
Fiber hardboard	0.2		
Fireclay brick 500°C	1.4		
Foam Glass	0.042		
Gasoline	0.15		
Glass	1.05		
Glass, Pearls, dry	0.18		
Glass, Pearls, saturated	0.76		
Class, window	0.96		
Glass, wool Insulation	0.04		
Glycerol	0.28		
Gold	310	312	310
Granite	1.7 - 4.0		
Gypsum or plaster board	0.17		
Hairfelt	0.05		
Hardboard high density	0.15		
Hardwoods (oak, maple..)	0.16		
Helium	0.142		
Hydrogen	0.168		
Ice (0°C, 32°F)	2.18		
Insulation materials	0.035 - 0.16		
Iridium	147		
Iron	80	68	60
Iron, wrought	59		
Iron, cast	55		
Kapok insulation	0.034		
Kerosene	0.15		
Lead Pb	35		
Leather, dry	0.14		
Limestone	1.26 - 1.33		
Magnesia insulation (85%)	0.07		
Magnesium	156		
Marble	2.6		

Thermal Conductivity & Coefficient of Expansiona

Substance	Thermal Conductivity (W/cm·°C)	Coefficient of Thermal Expansion (ppm/°C)	Density (g/cm^3)	Specific Thermal Conductivity[b] (W/cm·°C)
Air (still)	0.0003			
Alumina	0.276			
Alumina (85%)	0.118			
Aluminum	2.165	0.23	2.7	0.81
Beryllia (99.5%)	1.969			
Beryllia (97%)	1.575			
Beryllia (95%)	1.161			
Beryllium	1.772			
Beryllium-Copper	1.063			
Boron Nitride	0.394			
Brass (70/30)	1.220			
Copper	3.937	0.17	8.9	0.45
Copper/Inv[c]/Copper	1.64	0.084	8.4	.020
Copper/Mo[d]/Copper	1.82	0.060	9.9	0.18
Copper/Mo[d]-Cu/Copper	2.45-2.80	0.60-0.10	9.4	0.26-0.30
Diamond (room temp)	6.299			
Epoxy	0.002			
Epoxy (thermally conductive)	0.008			
FR-4 (G-10)	0.003			
GaAs	0.591			
Glass	0.008			
Gold	2.913			
Heatsink Compound	0.004			
Helium (liquid)	0.000307			
Invar	0.11	0.013	8.1	0.014
Iron	0.669			
Kovar	0.17	0.59	8.3	0.020
Lead	0.343			
Magnesium	1.575			
Mica	0.007			
Molybdenum	1.299			
Monel	0.197			

Mylar	0.002			
Nickel	0.906			
Nitrogen (liquid)	0.001411			
Phenolic	0.002			
Platinum	0.734			
Sapphire (a-axis)	0.32			
Sapphire (c-axis)	0.35			
Silicon (pure)	1.457			
Silicon (0.0025 Ω-cm)	1.457			
Silicon Carbide	0.90			
Silicon Dioxide (amorphous)	0.014			
Silicon Dioxide (quartz, a-axis)	0.059			
Silicon Dioxide (quartz, c-axis)	0.11			
Silicone Grease	0.002			
Silicone Rubber	0.002			
Silicon Nitride	0.16 - 0.33			
Silver	4.173			
Stainless Steel (321)	0.146			
Stainless Steel (410)	0.240			
Steel (low carbon)	0.669			
Teflon	0.002			
Tin	0.630			
Titanium	0.219	0.086	4.4	0.016
Tungsten	1.969			
Water	0.0055			
Zinc	1.024			

a: Approximate values from 0 °C to 100 °C
b: Thermal conductivity divided by specific gravity (introduced by Dr. Carl Zweben & K.A. Schmidt)
c: Invar
d: Molybdenum

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